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CALCULATION OF WEEKLY AVERAGES

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Introduction

Averages over a shorter period than a month are often required. Five-day averages have been chosen by some workers, and a five-day period has much to recommend it; in particular, neglecting February 29 in leap years, the year is exactly divisible into 73 five-day periods. However, for climatological and agricultural purposes the week has been used for short-period means; and averages have been published for many years. Two kinds of week are in use:

Weekly Weather Report week (.W.W.R. week), which runs from Sunday to Saturday Week 1 is the first with most of its days in the New Year, i.e. Sunday falls between December 29 and January 4; Week 2 is seven days later, and so on; during about one year in five there is a 53rd week beginning on December 27 or 28. Data from such weeks have been summed and meaned in a few instances. Averages derived in this way can only refer to periods of seven consecutive days distributed evenly over 13 consecutive dates in the year. Thus, neglecting leap years, a 35-year average of Week 2 contains data from 5 days each dated January 5 and January 17, from 10 days each dated January 6 and January 16, and so on, building up to a maximum of 35 days dated January 11.

Shaw week, which runs: Nov. 6-12, Nov. 13-19, etc., to Oct. 27-Nov. 4 or Oct. 26-Nov. 3 (if a leap year). Week 9 begins on January 1, (N.B. not Week 1). True long-term weekly averages from data grouped in Shaw weeks can be formed by ordinary summing and meaning, but, since the scheme was not inaugurated until January 1, 1935, only 25 years of readily extractable data will be available by the beginning of 1960. Data for a longer period can only be extracted later or very laboriously from daily values.

General

In order to obtain weekly averages quickly from such data as are available estimates can be made from the monthly averages. The usefulness of such estimates depends on the method of estimation and also whether the element of which the average is desired changes smoothly from week to week. Clearly rainfall and humidity do not vary smoothly enough (the first six harmonics of monthly rainfall - all that can be calculated from 12 monthly averages - are all of the same magnitude, and we cannot therefore assume other harmonics are negligible). It is also doubtful whether useful estimates of weekly average sunshine can be made; for example the first harmonic of mean daily sunshine at Kew Observatory as calculated from monthly means has a maximum in late June showing little more than the dependence of sunshine totals on the length of day; the next five harmonics are all of the same magnitude. However, temperature - whether earth temperature or air temperature - shows a decrease in amplitude as the number of the harmonic increases. Useful estimates of weekly average temperature may therefore be made from the monthly averages.

Methods

Graphical estimation - The monthly averages are plotted in histogram form on a graph paper and the curve of annual temperature variation can be drawn freehand so that the small areas on either side the curve formed by the histogram and the curve are equal in area. In order to save time consumed in the laborious counting of squares in these small areas the curve has often been drawn through the values of the average temperature plotted at the mid-point of each month. The consequent error is small, and even that can be

reduced by increasing the departure from annual mean of each monthly average by 1.15 per cent before plotting at the mid-month date[*]. This small correction takes into account the first harmonic of the annual variation of temperature. The residual error is less than 0.1°F. The weekly averages may then be read off the curve of annual variation at the mid point of each week.

Use of harmonic analysis - It is possible closely to approximate to the curve of the annual variation of temperature by combination of harmonics. It is then a simple matter to calculate the average temperature at any time of the year, in particular the average temperature at the mid point of any week. It can be shown that the average temperature for the week in such harmonic representation is within ± 0.1°F of the temperature at mid week obtained from the representation.

Craddock has described[**] a simple method of finding the best fitting two term harmonic for the curve of annual variation. This method is suitable for machine use since each harmonic coefficient is the sum of 12 products (one for each month). However, for air temperature, the harmonics have already been calculated and published for a number of stations[**/]. The harmonics have not been calculated for earth temperature, and thus some preliminary work would have to be done if the method were to be used for earth temperatures.

Weekly averages calculated by this method will usually be within ± 0.5°F of the true value; but there will be occasions at certain times of the year (early February, mid March, early April, late May and early June, late June and mid November) when the calculated averages may be more than 1°F in error because of naturally occurring temperature singularities[§]. Such discrepancies must occure with a method of estimation from but two harmonics for even the second harmonic takes into account variations on a seasonal rather than a monthly scale.

An alternative method of calculation has been developed in the Agricultural Meteorology Branch. This involves fitting a simple harmonic wave to three months of data to calculate the weekly averages occurring in the middle month. The advantages of this method are that the actual harmonic coefficients need not be calculated at any stage, and that the assumed curve which is fitted to the observation varies from month to month. In this way the contributions of the second and higher harmonics are absorbed into the monthly variation of the phase and amplitude of the first harmonic of the annual variation. Since the fitted curve varies from month to month it may be necessary to smooth the values assigned to an occasional week at the beginning or end of a month; this can be done very quickly by forming a column of first differences which, in itself, forms a useful device to check the accuracy of the calculations.

It can be shown that if a simple harmonic curve of period T (= 1 yr) is fitted to three successive month's observations (θ_{m-1}, θ_m, θ_{m+1} being the mid-month temperatures at times t_{m-1}, t_m, t_{m+1}) then if θ_0 is the annual mean temperature and suffices w refer to mid-week values,

$$\theta_w = \theta_m + (\theta_0 - \theta_m)\left\{1 - \cos\frac{2\pi(t_w - t_m)}{T}\right\} - (\theta_{m-1} - \theta_{m+1})\sin\frac{2\pi(t_w - t_m)}{T}$$

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[*] BILHAM, E. G.; the use of mean values in climatological analysis. Quart. J. R. met. Sc., London, 44, 1918, p.41.

[**] CRADDOCK, J. M.; The variation of normal air temperature over the northern hemisphere during the year. Met. Res. Pap., London, No.917, 1955

[**/] CRADDOCK, J. M.; The harmonic representation of the annual temperature variation in different parts of the British Isles. Met. Res. Pap., London, No.970, 1956.

[§] CRADDOCK, J. M.; The representation of the annual temperature variation over central and northern Europe by a two term harmonic form. Met. Res. Pap., London, No.915, 1955.

the factors $\{1 - \cos 2\pi(t_w - t_m)/T\}$ and $\sin 2\pi(t_w - t_m)/T$ apply equally to all temperature elements at all stations, and may therefore be tabulated for each week. The other terms are easily determined from a series of 12 monthly averages by simple differencing, since

$$\theta_m = \bar{\theta}_m - \frac{1}{24}\Delta^2\bar{\theta}_m$$

$$\theta_{m-1} - \theta_{m+1} = (\theta_{m-1} - \theta_m) + (\theta_m - \theta_{m+1}) = S\Delta\theta_m$$

where bars refer to monthly averages, $S\Delta\theta_m$ is the sum of neighbouring first differences of the mid-month temperatures, and $\Delta^2\bar{\theta}_m$ is the second difference of monthly average temperatures. The whole calculation can be performed on Sheets 1 and 2. The multiplications in columns (12) and (13) can be performed sufficiently accurately with a slide rule or even more reliably by means of specially constructed multiplication tables. The whole calculation for one station takes about 45 min. or less than 1 min. for each weekly average.

The accuracy of the method is illustrated in the Appendix by the weekly average earth temperature calculated for Rothamsted (1 ft) and Cambridge (1 ft and 4 ft) compared with the averages computed from weekly means (Shaw weeks extracted from daily values), and also with a graphical estimation. The results are summarised below:-

	Estimated by calculation				Graphical estimates	
	Unsmoothed		Smoothed			
	Largest diff.	R.M.S. diff.	Largest diff.	R.M.S. diff.	Largest diff.	R.M.S. diff.
	degrees Fahrenheit					
Rothamsted 1 ft	-0.8	0.37	±0.8	0.36	+1.1	0.38
Cambridge 1 ft	±0.7	0.32	±0.7	0.32	+0.9	0.39
Cambridge 4 ft	+0.3	0.11	+0.3	0.11	+0.5	0.19

R.M.S. = root mean square

Smoothing leads to only a little improvement in the calculated estimates which are slightly closer to the actual averages than the estimates read off a graph, the drawing of which must be a little subjective. The large differences occurred in the same weeks at both stations but not generally at the same times of year as found by Craddock in fitting a two-harmonic curve. It seems therefore that, at the expense of smoothness at the beginning or end of the month, the calculated averages are, on the whole, closer to the actual averages than by fitting a two-harmonic curve to the monthly averages. This follows from the contrast between the annual basis of the two term harmonic calculation and the monthly basis of the simple-harmonic calculation. In fact, monthly averages derived from the two-term harmonic caculation may differ slightly from the true monthly averages on which they are based; whereas, from the nature of the method of calculation by months, monthly averages derived from the simple-harmonic calculation are unchanged.

Time taken

It may be useful to compare the time taken to produce weekly averages by hand by the various methods.

(i) W.W.R. weeks. A year's weekly means for each station are available on the same form (A.M. Form 925). Extraction of data for a period of 30 yr would take about $1\frac{1}{2}$ hr, summing and meaning about 3 hr. The total time would therefore be $4\frac{1}{2}$ hr. The weekly averages thus produced would be over-smoothed, and only six week 53's would appear so that the mean for week 53 would have to be estimated by interpolation.

(ii) Shaw weeks. Weekly means are only available by weeks (all stations on one report), so that only one weekly value at any station would be available from each sheet. It would be quicker to take the weekly means from the actual monthly returns. Extraction would therefore take

about 3 hr. (5 hr. from the Ministry of Agriculture, Fisheries and Food Weekly Weather Reports); summing and meaning would again take about 3 hr. giving a total time of 6 hr. or 8 hr. for a period of 30 yr. However 30 yr. weekly means will not be available until January 1965. The weekly averages would be true averages.

(iii) Graphical method of estimation. Extraction of monthly averages and preliminary estimation of mid-month values would take about 10 min.; plotting and drawing the curve of annual variation would take about 15 min.; reading off the weekly averages about 15 min.; total time about 40 min.

(iv) Estimation by monthly simple harmonic. Preliminary extraction and calculations (Sheet 1) take about 10 min; two columns of multiplication take about 20 min. (with slide rule 25 min.); one column of additions takes about 10 min; writing down a column of first differences and smoothing perhaps half a dozen values takes another 5 min; total time 45 min. Three checks are incorporated in addition to the final differencing.

(v) Estimation by two-term harmonic synthesis. Preliminary extraction and harmonic analysis by Craddock's method take about 30 min. providing no mistake has been made (maximum time 1 hr.); four columns of multiplication take about 50 min. (by slide rule); addition of five quantities instead of three for method (iv) takes 20 min; writing down a column of first differences as a check takes another 5 min; total time about 2 hr. if the harmonic coefficients have to be calculated first, or $1\frac{1}{4}$ hr. if harmonic coefficients are known. It is assumed that sheets similar to Sheet 2 are available with all four multipliers printed in the appropriate line for each week. They are not available yet and they would take more than three times as long as Sheet 2 to prepare because there would be no repetitions from Shaw weeks 9 to 52.

Conclusions

Little is to be gained by estimation of weekly averages from monthly averages for any elements other than air temperature, earth temperature and possibly sunshine. Extraction and hand computation of 30-yr averages from W.W.R. weeks can be performed in about $4\frac{1}{2}$ hr. but these averages will be smoothed more than actual averages computed from Shaw weeks. Only 24 years of data are, as yet, readily extractable for Shaw weeks. For temperature the smoothest averages will be derived from two-term harmonic synthesis, the next smoothest will be derived from the graphical method, averages computed for W.W.R. weeks will be about as smooth as averages estimated by the monthly simple - harmonic method, and the least smooth averages will be the actual averages derived from Shaw weeks. The most rapid hand method of estimation is the graphical method (40 min) followed very closely by the monthly simple harmonic method (45 min.).

Use of machine methods would, of course, alter the whole picture.

APPENDIX - Actual and estimated weekly averages

SHAW WEEK No.	Month	mid date	Rothamsted 1 ft. Actual	Calc.	Diff.	Graph.	Diff.	Cambridge 1 ft. Actual	Calc.	Diff.	Graph.	Diff.	Cambridge 4 ft. Actual	Calc.	Diff.	Graph.	Diff.
9		4	38.7	38.6	-0.1	38.4	-0.3	39.7	39.5	-0.2	39.4	-0.3	44.1	44.1	0.0	43.9	-0.2
10		11	38.2	38.1	-0.1	38.2	0.0	39.2	39.2	0.0	39.1	-0.1	43.6	43.5	-0.1	43.4	-0.2
11	Jan.	18	38.0	38.0	0.0	37.9	-0.1	38.9	39.0	+0.1	38.9	0.0	43.2	43.1	-0.1	43.0	-0.2
12		25	37.7	37.9	+0.2	37.8	+0.1	38.7	38.6	-0.1	38.8	+0.1	42.7	42.8	+0.1	42.7	0.0
13		1	38.2	37.7	-0.5	37.8	-0.4	39.2	38.9	-0.3	38.9	-0.3	42.5	42.5	0.0	42.5	0.0
14		8	38.1	37.7	-0.4	37.8	-0.3	39.3	39.0	-0.3	39.1	-0.2	42.5	42.4	-0.1	42.3	-0.2
15	Feb.	15	37.9	37.9	0.0	37.9	0.0	39.3	39.3	0.0	39.4	+0.1	42.4	42.3	-0.1	42.3	-0.1
16		22	37.8	38.3	+0.5	38.3	+0.5	39.4	39.8	+0.4	39.9	+0.5	42.3	42.4	+0.1	42.4	+0.1
17		1	38.2	38.5	+0.3	38.8	+0.6	39.9	40.1	+0.2	40.5	+0.6	42.4	42.3	-0.1	42.6	+0.2
18		8	38.5	39.2	+0.7	39.4	+0.9	40.4	40.9	+0.5	41.2	+0.8	42.6	42.7	+0.1	42.8	+0.2
19	Mar.	15	39.5	40.1	+0.6	40.1	+0.6	41.4	41.9	+0.5	42.0	+0.6	42.9	43.1	+0.2	43.1	+0.2
20		22	41.7	41.0	-0.7	41.2	-0.5	43.5	42.9	-0.6	43.0	-0.5	43.6	43.7	+0.1	43.7	+0.1
21		29	42.9	42.1	-0.8	42.4	-0.5	44.8	44.1	-0.7	44.1	-0.7	44.6	44.4	-0.2	44.4	-0.2
22		5	43.8	43.5	-0.3	43.6	-0.2	46.0	45.7	-0.3	45.5	-0.5	45.4	45.4	0.0	45.3	-0.1
23		12	45.1	44.9	-0.2	44.9	-0.2	47.3	47.1	-0.2	47.1	-0.2	46.2	46.3	+0.1	46.3	+0.1
24	Apr.	19	46.3	46.3	0.0	46.4	+0.1	48.4	48.6	+0.2	48.7	+0.3	47.2	47.2	0.0	47.3	+0.1
25		26	47.1	47.8	+0.7	47.9	+0.8	49.3	50.0	+0.7	50.1	+0.8	47.9	48.2	+0.3	48.2	+0.3
26		3	48.4	49.0	+0.6	49.5	+1.1	50.7	51.2	+0.5	51.6	+0.9	48.7	48.9	+0.2	49.2	+0.5
27		10	50.5	50.6	+0.1	51.0	+0.5	52.6	52.7	+0.1	52.9	+0.3	49.8	50.0	+0.2	50.2	+0.4
28	May	17	52.3	52.1	-0.2	52.4	+0.1	54.2	54.2	0.0	54.3	+0.1	51.0	51.1	+0.1	51.3	+0.3
29		24	54.0	53.8	-0.2	53.9	-0.1	55.9	55.7	-0.2	55.8	-0.1	52.2	52.2	0.0	52.4	+0.2
30		31	55.6	55.2	-0.4	55.5	-0.1	57.5	57.1	-0.4	57.2	-0.3	53.4	53.3	-0.1	53.5	+0.1
31		7	57.4	57.1	-0.3	57.0	-0.4	59.1	58.7	-0.4	58.7	-0.4	54.6	54.6	0.0	54.8	+0.2
32	June	14	58.3	58.4	+0.1	58.4	+0.1	59.9	59.9	0.0	60.1	+0.2	55.7	55.7	0.0	55.8	+0.1
33		21	59.3	59.6	+0.3	59.6	+0.3	60.9	61.1	+0.2	61.2	+0.3	56.5	56.7	+0.2	56.9	+0.4
34		28	60.4	60.6	+0.2	60.6	+0.2	61.8	62.0	+0.2	62.2	+0.4	57.4	57.6	+0.2	57.8	+0.4

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APPENDIX - continued

SHAW WEEK No.	Month	mid date	Rothamsted 1 ft. Actual	Calc.	Diff.	Graph.	Diff.	Cambridge 1 ft. Actual	Calc.	Diff.	Graph.	Diff.	Cambridge 4 ft. Actual	Calc.	Diff.	Graph.	Diff.
35		5	61.3	61.3	0.0	61.4	+0.1	62.7	62.8	+0.1	62.8	+0.1	58.2	58.3	+0.1	58.5	+0.3
36		12	62.1	61.9	-0.2	62.0	-0.1	63.7	63.4	-0.3	63.4	-0.3	58.9	59.0	+0.1	59.2	+0.3
37	July	19	61.9	62.2	+0.3	62.2	+0.3	63.8	63.7	-0.1	63.7	-0.1	59.6	59.5	-0.1	59.6	0.0
38		26	62.2	62.4	+0.2	62.3	+0.1	64.0	64.1	+0.1	63.8	-0.2	60.0	60.0	0.0	60.0	0.0
39		2	61.9	62.0	+0.1	62.1	+0.2	63.9	63.9	0.0	63.8	-0.1	60.4	60.4	0.0	60.3	-0.1
40		9	61.8	61.8	0.0	61.7	-0.1	63.8	63.7	-0.1	63.6	-0.2	60.6	60.6	0.0	60.6	0.0
41	Aug.	16	61.2	61.3	+0.1	61.3	+0.1	63.2	63.3	+0.1	63.1	-0.1	60.7	60.7	0.0	60.7	0.0
42		23	60.6	60.7	+0.1	60.7	+0.1	62.7	62.7	0.0	62.5	-0.2	60.7	60.7	0.0	60.6	-0.1
43		30	60.5	59.8	-0.7	60.0	-0.5	62.5	62.0	-0.5	61.8	-0.7	60.6	60.5	-0.1	60.4	-0.2
44		6	59.5	59.1	-0.4	59.0	-0.5	61.5	61.2	-0.3	60.9	-0.6	60.4	60.4	0.0	60.2	-0.2
45		13	58.0	58.0	0.0	57.9	-0.1	60.2	60.1	-0.1	59.9	-0.3	60.0	59.9	-0.1	59.8	-0.2
46	Sept.	20	56.6	56.6	0.0	56.4	-0.2	58.7	58.7	0.0	58.6	+0.1	59.3	59.3	0.0	59.3	0.0
47		27	54.8	55.2	+0.4	54.9	+0.1	56.9	57.3	+0.4	57.2	+0.3	58.5	58.6	+0.1	58.5	0.0
48		4	53.6	53.4	-0.2	53.4	-0.2	55.6	55.4	-0.2	55.7	+0.1	57.7	57.7	0.0	57.6	-0.1
49		11	52.2	51.8	-0.4	51.7	-0.5	54.1	53.7	-0.4	54.1	0.0	56.7	56.7	0.0	56.6	-0.1
50	Oct.	18	50.7	50.1	-0.6	50.0	-0.7	52.4	52.0	-0.4	52.3	-0.1	55.7	55.6	-0.1	55.4	-0.3
51		25	48.2	48.5	+0.3	48.3	+0.1	50.1	50.3	+0.2	50.5	+0.4	54.5	54.4	-0.1	54.3	-0.2
52		1	46.4	46.6	+0.2	46.6	+0.2	48.2	48.4	+0.2	48.6	+0.4	53.0	53.1	+0.1	52.8	-0.2
1		9	44.7	45.0	+0.3	45.0	+0.3	46.3	46.7	+0.4	46.7	+0.4	51.5	51.6	+0.1	51.4	-0.1
2	Nov.	16	43.2	43.6	+0.4	43.5	+0.3	44.7	45.2	+0.5	45.0	+0.3	50.1	50.3	+0.2	50.2	+0.1
3		23	43.0	42.3	-0.7	42.6	-0.4	44.5	43.8	-0.7	43.8	-0.7	49.1	49.2	+0.1	49.1	0.0
4		30	41.4	41.1	-0.3	41.5	+0.1	42.9	42.5	-0.4	42.4	+0.5	48.1	48.1	0.0	48.0	-0.1
5		7	40.1	40.5	+0.4	40.6	+0.5	41.5	41.8	+0.3	41.6	+0.1	47.0	47.0	0.0	47.0	0.0
6		14	39.8	39.7	-0.1	39.8	0.0	41.0	40.9	-0.1	40.8	-0.2	46.0	46.1	+0.1	46.1	+0.1
7	Dec.	21	38.8	39.0	+0.2	39.2	+0.4	40.1	40.2	+0.1	40.3	+0.2	45.3	45.2	-0.1	45.3	0.0
8		28	38.7	38.5	-0.2	38.6	-0.1	39.7	39.6	-0.1	39.8	+0.1	44.5	44.5	0.0	44.6	+0.1

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ESTIMATION OF WEEKLY MEANS

	$\bar{\theta}$ (1)	$\Delta\bar{\theta}$ (2)	$\Delta^2\bar{\theta}$ (3)	$-\frac{1}{24}\Delta^2\bar{\theta}$ (4)	θ (5)	$\theta_a - \theta$ (6)	$S\Delta\theta$ (7)
Dec.							
Jan.							
Feb.							
Mar.							
Apr.							
May							
June							
July							
Aug.							
Sept.							
Oct.							
Nov.							
Dec.							
Jan.							
	Checks:		+ −			+ −	+ −
Annual Mean							

INSTRUCTIONS

1. Enter monthly means in column (1), repeating December and January.
2. Enter in column (2) differences between neighbouring values in column (1), subtracting succeeding values, e.g. Dec.-Jan., Jan.-Feb., etc.
3. Enter in column (3) differences between neighbouring values in column (2), subtracting succeeding values. Total of column should be 0.0.
4. Multiply each value in column (3) by -1/24 to obtain column (4).
5. Add column (4) to column (1) to obtain mid-month values in column (5). Repeat values for Dec. and Jan.
6. Subtract each value in column (5) from annual mean to obtain column (6). Total of column should be between $\pm$0.6.
7. Subtract next-but-one succeeding values in column (5) to obtain column (7), e.g. Dec.-Feb., Jan.-Mar., Feb.-Apr., etc. Total of column should be 0.0.
8. Enter columns (7), (6) and (5) in columns (9) (11) and (14) on Sheet 2.
9. Multiply column (8) by column (9) and enter in column (12); multiply column (10) by column (11) and enter in column (13); add together columns (12), (13) and (14) to obtain weekly means.

SHAW WEEK No.	Month	Mid-date	$S\Delta\theta$ (8)	(9)	$\theta_o - \theta$ (10)	(11)	(8)x(9) (12)	(10)x(11) (13)	θ (14)	Weekly Mean
9		4	0.205		0.021					
10	Jan.	11	0.086		0.004					
11		18	-0.034		0.0006					
12		25	-0.154		0.012					
13		1	0.230		0.027					
14	Feb.	8	0.112		0.006					
15		15	-0.009		0					
16		22	-0.129		0.008					
17		1	0.255		0.033					
18		8	0.137		0.009					
19	Mar.	15	0.017		0					
20		22	-0.103		0.005					
21		29	-0.222		0.025					
22		5	0.180		0.016					
23	Apr.	12	0.060		0.0024					
24		19	-0.060		0.0024					
25		26	-0.180		0.016					
26		3	0.222		0.025					
27	May	10	0.103		0.0053					
28		17	-0.017		0					
29		24	-0.137		0.009					
30		31	-0.255		0.033					
31		7	0.146		0.011					
32	June	14	0.026		0					
33		21	-0.095		0.0045					
34		28	-0.213		0.023					
35		5	0.188		0.018					
36	July	12	0.069		0.0024					
37		19	-0.052		0.0013					
38		26	-0.171		0.015					
39		2	0.239		0.029					
40		9	0.120		0.007					
41	Aug.	16	0		0					
42		23	-0.120		0.007					
43		30	-0.239		0.029					
44		6	0.163		0.013					
45	Sept.	13	0.043		0.0009					
46		20	-0.077		0.003					
47		27	-0.197		0.019					
48		4	0.205		0.021					
49	Oct.	11	0.086		0.004					
50		18	-0.034		0.0006					
51		25	-0.154		0.012					
52		1	0.247		0.031					
1		9	0.112		0.006					
2	Nov.	16	-0.009		0					
3		23	-0.129		0.008					
4		30	-0.247		0.031					
5		7	0.154		0.012					
6		14	0.034		0.0006					
7	Dec.	21	-0.086		0.004					
8		28	-0.205		0.021					